Early Journal Content on JSTOR, Free to Anyone in the World

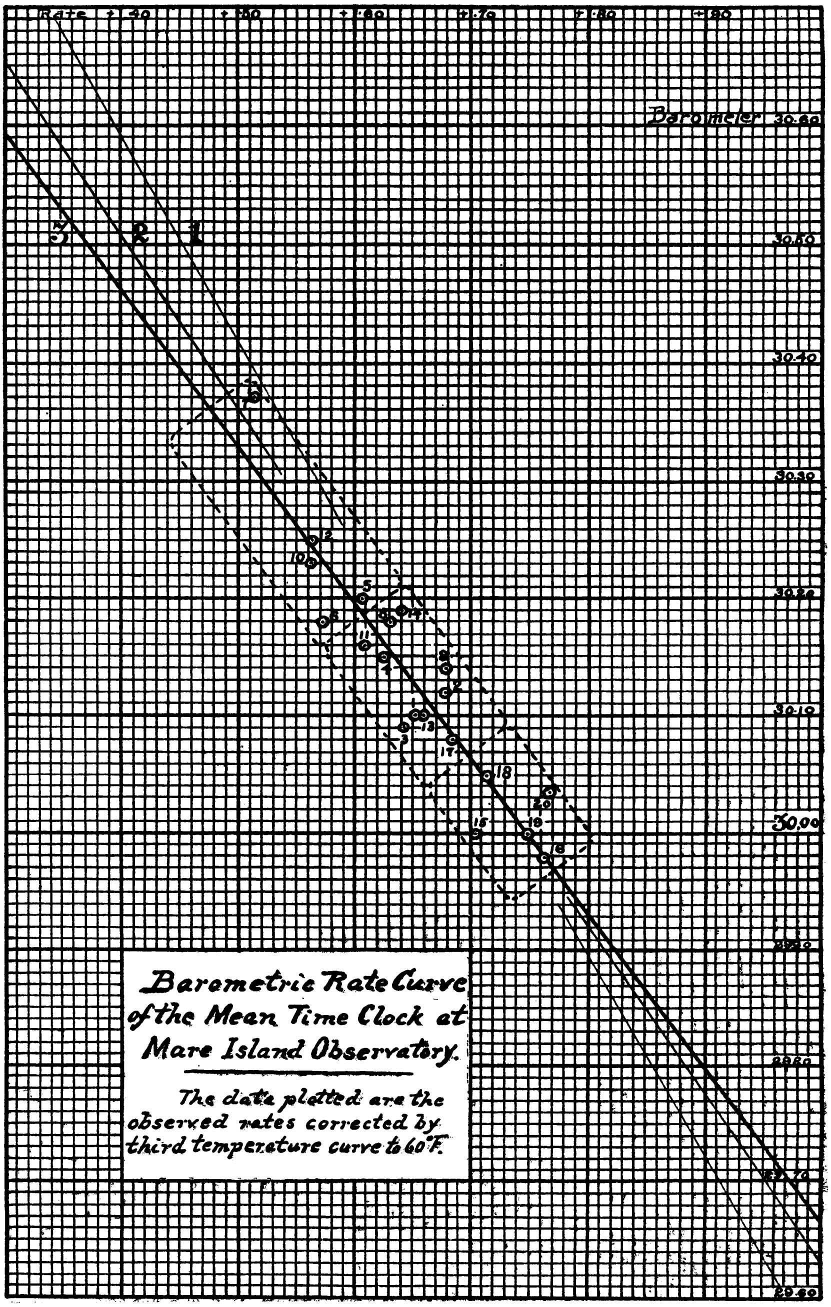
This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.



Barometric Rate Curve of the Mean Time Clock at Mare Island Observatory.

The data plotted are the observed rates corrected by third temperature curve to 60° F.

PUBLICATIONS
OF THE
Astronomical Society of the Pacific.

VOL. XI. SAN FRANCISCO, CALIFORNIA, JUNE 1, 1899. NO. 68.

CLOCK-RATES AND BAROMETRIC PRESSURE AS ILLUSTRATED BY THE MEAN-TIME CLOCK AND THREE CHRONOMETERS AT MARE ISLAND OBSERVATORY;

WITH A BRIEF ACCOUNT OF THE OBSERVATORY.

BY ENSIGN EVERETT HAYDEN, U. S. N.

The principal work of the observatory at the Mare Island Navy Yard, California, is the care and rating of chronometers for naval vessels and the sending out of the daily noon-signal, which the wires of the Western Union Telegraph Company flash to every part of the Pacific Coast. The time service of the Naval Observatory at Washington extends as far as Ogden, Utah. West of that point, standard time is supplied by this observatory. These two functions fit in very well together; it is of vital importance to have absolutely correct time, by which to rate chronometers for navigation, both at the observatory (where forty are now on hand and rated daily) and at every seaport along the coast, and the time transmitted for this special purpose is easily made available to the general public also. A shipmaster at San Diego or Seattle, or any other port, can take his chronometer to the telegraph office any week-day in the year, and for the five minutes ending at mean noon of the 120th meridian compare it directly with the clock at Mare Island Observatory, the pulsations of whose pendulum are transmitted instantaneously and audibly through the thousand miles or so of intervening space by the magic of electricity.

The accuracy of the mean-time clock at the Mare Island Observatory — not merely to a second or two, but to a hundredth of a second a day, because even a small daily error becomes large if it accumulates for a few days — is thus a matter of far-reaching importance.

Some further remarks relative to the observatory, its equipment, work, and history, are appended at the end of this paper, but the primary object is to explain the method that I have adopted in order to find the exact rate of the mean-time clock by means of the observed (corrected) reading of the barometer, irrespective of everything else except a very slight temperature correction, and subject only to disturbances from earthquakes, unfortunately somewhat frequent here, and against which even the best pendulum clock is almost powerless. This clock, however, seems to be less subject to their influence than the sidereal clock, possibly because it faces southwest, while the other faces south, the shocks coming mostly from northwest.

In the great earthquake here on the night of March 30, 1898, for example, which shook down houses, and, of course, stopped all the pendulum clocks, the sidereal clock stopped at $11^h\ 42^m\ 17^s$ P.M., 120th meridian time, while the mean-time clock ran thirteen seconds longer.

The clock (No. 624, by E. HOWARD & Co., Boston) has a second's pendulum, with heavy cylindrical bob, mercury temperature compensation, gravity escapement, double case, and is bolted to a substantial masonry pier. Its error and rate are found ordinarily by means of stellar observations with a meridian transit instrument, in connection with the sidereal clock and an electric chronograph.* It has been running here for fifteen years, and was last cleaned and oiled about five years ago.

The special advantage of the barometric rate, the method of obtaining which, and its results, are now to be described, consists in the facility with which it can be obtained, for both short and long intervals, its reliability, its availability, even in cloudy weather, when star-sights cannot be had, and finally its value for use in connection with old records of chronometer rates where daily comparisons with the same clock were recorded.

The plates present graphically the data contained in the accompanying tabular statement, and with a brief explanation will make clear the method followed. It may be said, to begin with, that it is customary in rating chronometers to adopt a ten-day period, from noon to noon, as the interval for which to note mean rates and temperatures, at the same time keeping a daily comparison-sheet, both as a check and to note maximum variations from the mean rate. My attempt to find a satisfactory barometric rate was based at the start upon this period, and the work developed to such an extent on these lines before final results were reached as to deter me from going back and adopting for this special investigation a period beginning about 9 P.M., when star-sights are exactly available. The mean rates used are therefore subject to some error in working up evening sights to noon of the following day, and are only given to the nearest hundredth of a second, while the corrections are carried out to the third decimal place. It is trusted that general averages have eliminated such errors; otherwise, they must still be present in the final results. The rate-curves are assumed to be straight lines within the limits of the diagrams.

---

* During the 200 days under consideration there were taken 100 sets of sights, aggregating 1,000 stars

The temperature is the mean of observations at noon daily of a Six's maximum and minimum thermometer kept in the chronometer-case in the middle of the room. This is found by trial to differ very little from the mean of hourly readings of a standard thermometer in the inner clock-case, read through glazed windows in the double doors. The barometer record is the two-hourly mean from copies of barograph sheets kindly supplied by the office of the United States Weather Bureau in San Francisco, corrected and reduced by the addition of .16 inch, and confirmed by curves drawn from my own observations of a standard mercurial barometer at the observatory.

The relative humidity is obtained from daily noon readings of an ordinary wet and dry bulb thermometer in the clock-room. This record is not regarded as of any special value, and need not be considered further than to say that it is shown graphically on the plate in connection with the curve showing final errors of the barometric rate, with which curve it is so inconsistent as not to justify further correction. The best inference that can be drawn from it seems to be that an increase of one per cent. above normal (84 per cent.) makes the clock run about $.01^s$ per day more slowly.

The tabular statement gives all the observed data; the data by which the successive approximate curves are drawn; the final errors of the barometric rate-curve at normal temperature (60° Fahr.) for each of the twenty periods; and finally, the accumulated error up to the end of each successive period, amounting in all to two hundred days:—

DATA AND RESULTS OF THE BAROMETRIC RATE OF THE

Period.	Ending at Noon,	No. of Days.	MEAN OBSERVED DATA. (Bar. Corrected and Reduced.) Temp.	Bar.	Rate. (gaining)	Rel. Humid.	Rate corrected to 60° F. by Temp. Curve No. 1.	BAROMETRIC RATE-CURVE NO. 1. Data.	Rate.	Error.†	Rate corrected to 60° F. by Temp. Curve No. 2.
			°F.	In.	Sec.	Per cent.					
1	Nov. 1	10	65.78	30.10	+.66	*80.0	.620	Means of Periods	.683	—.063	.638
2	13	12	61.29	30.12	.68	80.0	.670	16, 17, 19 20, 21 :	.672	—.002	.676
3	21	8	57.94	30.09	.64	82.9	.654	Bar. 30.013	.689	—.035	.646
4	Dec. 1	10	54.85	30.15	.62	84.6	.650	Rate, .737	.653	—.003	.637
5	11	10	54.28	30.20	.60	78.1	.635		.624	+.011	.619
6	21	10	47.78	30.18	.56	86.5	.635	Periods 2, 3, 4, 5,	.635	0	.600
7	31	10	46.98	30.37	.50	84.8	.580	9, 10, 12, 14, 15, 18:	.526	+.054	.543
8	Jan. 10	10	48.18	30.18	.62	89.2	.692	Bar. 30.126	.635	+.057	.658
9	20	10	52.55	30.14	.67	90.6	.716	Rate, .662	.660	+.056	.694
10	30	10	57.68	30.23	.56	81.0	.574		.606	—.032	.567
11	Feb. 9	10	50.93	30.16	.60	83.8	.657	Periods 6, 7, 8, 11, 13 :	.648	+.009	.630
12	19	10	56.08	30.25	.56	85.8	.584	Bar.	.595	—.011	.573
13	Mar. 1	10	61.20	30.10	.66	79.0	.652	30.246 Rate,	.683	—.031	656
14	11	10	59.25	30.19	.64	82.0	.643	.602	.630	+.013	.641
15	21	10	55.13	30.00	.70	87.3	.730	Points of	.740	—.010	.716
16	31	10	58.43	29.98	.76	86.9	.769	Curve: 30.60	.751	+.018	.765
17	Apr. 10	10	64.00	30.08	.69	86.3	.663	.393 and	.695	—.032	.675
18	20	10	64.65	30.05	.72	83.4	.688	29.60 .972	.711	—.023	.703
19	30	10	60.70	30.00	.75	84.0	.745	Angle, 59°55′	.740	+.005	.748
20	May 10	10	62.15	30.035	.77	83.7	.755	45″	.720	+.035	.762
Mean for 200 days			56.53	30.13	+.65	84.0					

---

* Relative Humidity for Period No. 1 assumed to be same as for No. 2. Data missing.

† In error of Barometric Rate, + signifies that it would make noon-signal too early; —, too late.

MEAN-TIME CLOCK AT MARE ISLAND OBSERVATORY.

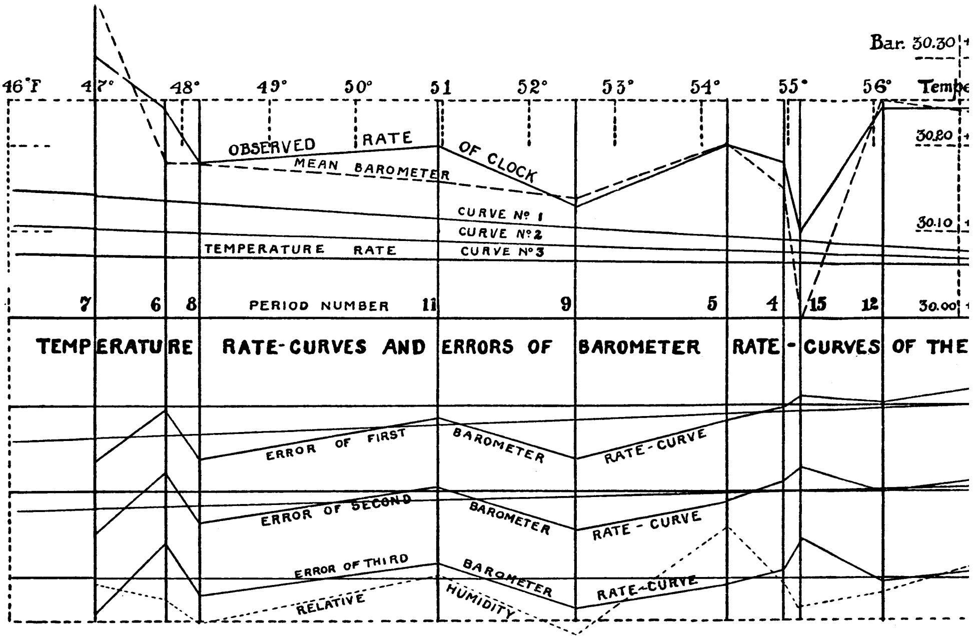
BAROMETRIC RATE-CURVE NO. 2.			Rate corrected to 60° F. by Temp. Curve No. 3.	BAROMETRIC RATE-CURVE NO. 3			TOTAL ERROR OF BAROMETRIC RATE FROM CURVE NO. 3.	
Data.	Rate.	Error.		Data.	Rate.	Error.	For Period.	To Date.
Means of Periods	.677	—.039	.652	Means of Periods	.672	—.020	—.20	—.20
16, 17, 19, 20, 21:	.664	+.012	.678	16, 17, 19, 20, 21:	.656	+.022	+.264	+.064
Bar. 30.013	.683	—.037	.642	Bar. 30.013	.680	—.038	—.304	—.24
Rate, .739	.649	—.012	.625	Rate, .739	.634	—.009	—.09	—.33
	.607	+.012	.605		.597	+.008	+.08	—.25
Periods 2, 3, 4, 5,	.621	—.021	.572	Periods 2, 3, 4, 5,	.610	—.038	—.38	—.63
9, 10, 12, 14, 15, 18:	.493	+.050	.512	9, 10, 12, 14, 15, 18:	.469	+.043	+.43	—.20
Bar. 30.126	.621	+.037	.631	Bar. 30.126	.610	+.021	+.21	+.01
Rate, .655	.649	+.045	.678	Rate, .650	.641	+.037	+.37	+.38
	.587	—.020	.562		.574	—.012	—.12	+.26
Periods 6, 7, 8, 11,	.635	—.005	609	Periods 6, 7, 8, 11,	.626	—.017	—.17	+.09
13:	.573	0	.563	13:	.558	+.005	+.05	+.14
Bar. 30.246	.677	—.021	.658	Bar. 30.246	.672	—.014	—.14	0
Rate, .580	.614	+.027	.640	Rate, .563	.604	+.036	+.36	+.36
	.745	—.029	.704		.747	—.043	—.43	—.07
Points of Curve:	.758	+.007	.761	Points of Curve:	.761	0	0	—.07
30 60 .335	.690	—.015	.684	30.60 .294	.687	—.003	—.03	—.10
and 29.60 1.017	.710	—.007	.714	and 29.60 1.049	.710	+.004	+.04	—.06
Angle, 55° 41′ 25″	.745	+.003	.749	Angle, 52° 56′ 05″	.747	+.002	+.02 *	—.04
	.720	+.042	.767		.721	+.046	+.46	+.42

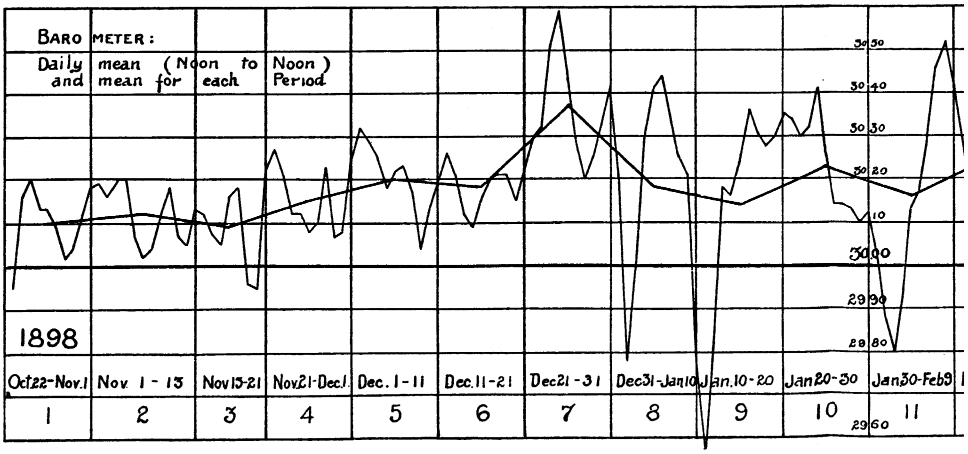
---

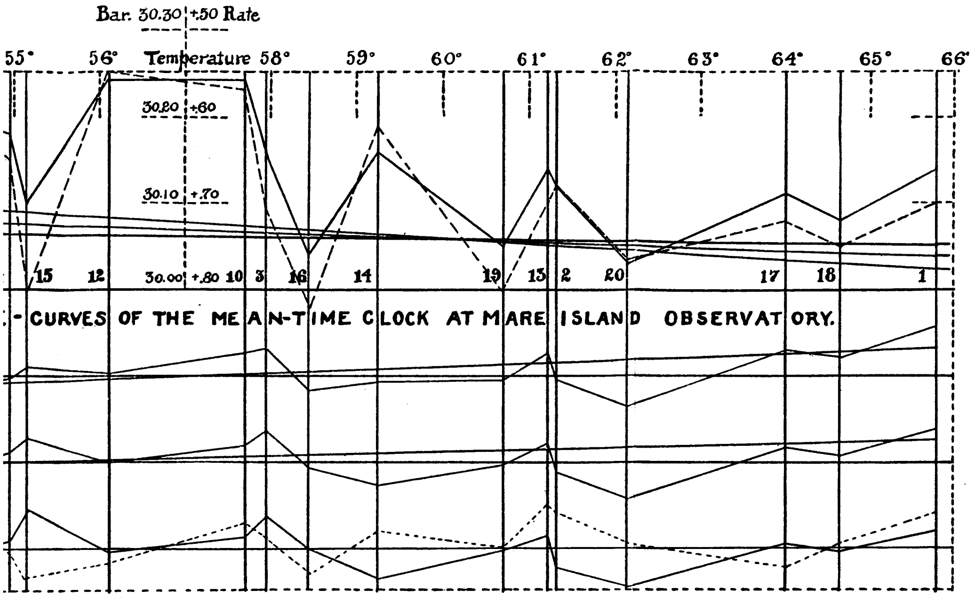
* Several light earthquake shocks occurred during the last period, and occasionally throughout the entire interval.

The first approximate temperature rate-curve is derived directly from the diagram where clock-rate and barometer for each period are plotted on ordinates of the temperature-scale; from these data the positions of points at high, medium, and low temperatures, at normal pressure of 30.00 inches, are estimated, and the temperature rate-curve drawn by means of these three points. Using this curve to reduce the observed rates to 60° Fahr., the first barometer rate-curve is drawn. From this the barometric rate is measured for the observed mean pressure of each period, and by comparison with the observed rates (as already corrected for temperature), the column and corresponding curve of errors are made out. The inclination of this last curve, as plotted on the temperature-sheet, furnishes an evident correction to the first temperature rate-curve. This correction, properly applied, gives the second temperature rate-curve. This process is then repeated once more, giving the third (and last) temperature and barometer rate-curves. The errors of the last-named curve for each period are given in the next to last column of the table, and shown graphically on the temperature-sheet, where, as stated above, the relative humidity curve also is shown. The last column gives the total accumulated error up to the end of each successive period, and is not shown graphically.

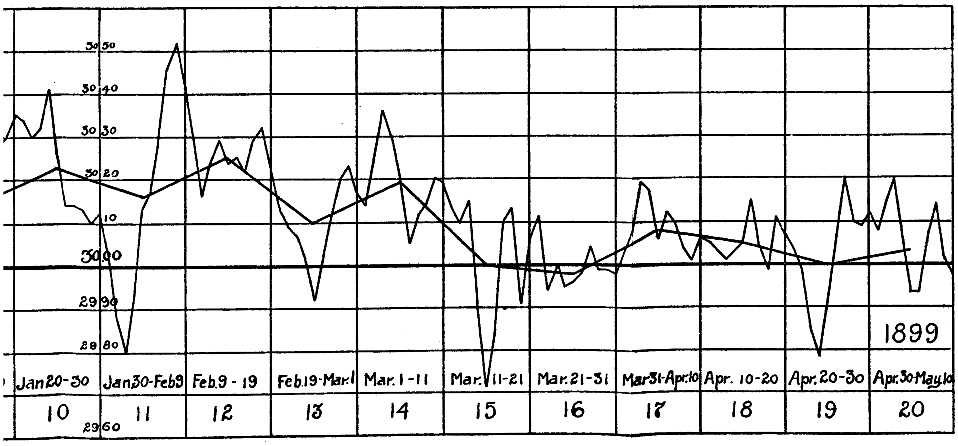
The last two columns may be assumed to represent the results that would have followed the use, without any star-sights at all, of the thermometric and barometric rate-curves ever since last October, under the actual conditions that prevailed, including a number of light and two or three rather sharp shocks of earthquake. In the last period, ending May 10th, I myself noticed and timed four shocks, of which one was sharp enough to be startling. It will be noticed that the two maximum errors for single periods are .46^{s} (in the last period) and .43^{s} (in the fifteenth). This is certainly not bad; an error of less than half a second in ten days, without using any star-sights, especially where we have an occasional earthquake to explain even this! But it will be seen, further, that twelve of the twenty periods have an error of only .21^{s} or less, and of these twelve there are seven with practically no error at all. Those specially interested can compare the periods where the error is larger or smaller, respectively, with the graphic record of mean daily barometer. It will be found that the larger discrepancies in rate correspond, generally, with erratic behavior of the barometer.


Bar. 30.30
46°F
47°
48°
49°
50°
51
52°
53°
54°
55°
56°
Tempe
OBSERVED RATE OF CLOCK
MEAN BAROMETER
CURVE No 1
CURVE No 2
TEMPERATURE RATE CURVE No 3
30.20
30.10
30.00
7
6
8
PERIOD NUMBER
11
9
5
4
15
12
TEMPERATURE RATE-CURVES AND ERRORS OF BAROMETER RATE-CURVES OF THE
ERROR OF FIRST BAROMETER RATE-CURVE
ERROR OF SECOND BAROMETER RATE - CURVE
ERROR OF THIRD BAROMETER RATE-CURVE
RELATIVE HUMIDITY


BAROMETER: Daily mean (Noon to Noon) and mean for each Period
30.50
30.40
30.30
30.20
30.10
30.00
29.90
29.80
29.60
1898
Oct22-Nov.1
Nov. 1 - 13
Nov13-21
Nov.21-Dec.1
Dec. 1-11
Dec.11-21
Dec21 - 31
Dec31-Jan10
Jan.10-20
Jan20-30
Jan30-Feb9
1
2
3
4
5
6
7
8
9
10
11



Bar. 30.30 +.50 Rate
55° 56° Temperature 58° 59° 60° 61° 62° 63° 64° 65° 66°
30.20 +.60
30.10 +.70
15 12 30.00 +.80 10 3 16 14 19 13 2 20 17 18 1
- CURVES OF THE MEAN-TIME CLOCK AT MARE ISLAND OBSERVATORY.



30 50
30 40
30 30
30 20
10
30.00
29 90
29 80
1899
Jan 20-30
Jan 30-Feb 9
Feb. 9 - 19
Feb. 19-Mar. 1
Mar. 1-11
Mar. 11-21
Mar. 21-31
Mar 31-Apr. 10
Apr. 10-20
Apr. 20-30
Apr. 30-May 10
10
29 60
11
12
13
14
15
16
17
18
19
20

Examining now the last column, or the accumulated error to end of each successive period, the maximum, $.63^s$, at end of the sixth period, is large in comparison with the rest, as the plus and minus errors cancel each other in a way that made me both surprised and pleased, leaving the total accumulated error one tenth of a second, or less, in ten of the twenty periods. In a word, had these rate-curves been used, without a single star-sight, since last October, the noon-signal would never have been more than six tenths of a second wrong, seldom more than one tenth, and at the end of April correct within a few hundredths of a second.

Having now examined the possibilities of error of the barometer-rate used alone, without the star-rate, let us next examine the possibilities of error of the star-rate without the barometer-rate. Take, for example, four days of abnormally high pressure, from noon, December 23d, to noon, December 26th, and of abnormally low pressure, January 9th to 12th. The mean temperature in the former period was 46°.9, and in the latter, 48°.7, giving a correction of —.01 to apply to the barometer-rate at 60°, in each case. Using the star-rate as actually observed at the beginning of each period, we have:—

Date	Dec. 23	24	25	26	Jan. 9	10	11	12
Barometer . . .	30.32	30.31	30.59	30.45	30.21	29.95	29.57	29.84
Star-rate	.53	.53	.53	.53	.63	.63	.63	.63
Bar.-rate.	.50	.35	.29	.40	.58	.77	1.06	.85
Error of star-rate Daily .	—.03	—.18	—.24	—.13	—.05	+.14	+.43	+.22
Error of star-rate Total .	—.03	—.21	—.45	—.58	—.05	+.09	+.52	+.74

In other words, the star-rate, used alone, is liable to a greater error in four days than the barometer-rate, used alone, is in two hundred days. In the examples given here, I have assumed the barometer-rate to be the correct rate, which it practically is, so far as these examples are concerned. The chances of four days of cloudy weather and no star-sights, more especially when the barometer is low, are of course very great.

I have applied the same method of investigation to the sidereal clock, and with very nearly as good results, and use both clocks in verifying the time before sending out the noon-signal. The two almost invariably agree within a few hundredths of a second, when their different rates are worked up according to this method. I always use the barometer-rate also in working up an evening star-sight to noon of the following day, and have used it to obtain chronometer rates from old records, where the rate only was wanted, the total error on Greenwich mean time not being required.

One cannot but form the impression, in studying these results, that a first-rate pendulum clock, well worn down to its bearings by long years of steady running, carefully mounted and protected from dust and from sudden change of temperature, and free from earth tremors of any kind, must keep even better time than we give it credit for, if only we make proper allowances for its regular and entirely reasonable variations under different conditions of temperature and pressure. An attempt was made in the present case to account for a part, at least, of the final errors by the effect of the other mean-time clock in the same room, but as the latter is always corrected daily at noon, the task proved impracticable. Similarly, an attempt to associate them with lunar or tidal influence failed, although it may be worth mentioning that the error-curve of the barometer-rate of the sidereal clock shows a very marked resemblance to a curve of the mean stage of the tide for each period at the entrance to San Francisco Bay. Finally, to try to allow for the lagging of the pendulum, barometric means were calculated for periods beginning a day earlier, but their use gave less favorable results.

Nevertheless, such attempts might succeed, under more favorable circumstances, and the final errors be reduced almost to the vanishing-point. If so, it could justly be claimed that the accuracy of motion of such a clock is actually comparable to that of the earth upon its axis, and that as a perfectly running machine it is, perhaps, the very best production of human brains and hands.

CHRONOMETER RATES AND BAROMETRIC PRESSURE.

After obtaining such satisfactory results with the barometric rate of the mean-time clock, I began an exhaustive investigation of the effect of changes of atmospheric pressure upon the rates of chronometers. In this work the data for the usual ten-day periods, already available, were supplemented by data obtained by means of the established thermometric and barometric rates of the clock and the recorded daily comparisons of the chronometers. Selecting five-day periods of high and low barometer, I was thus enabled to obtain the rates of the chronometers for those periods with great confidence, irrespective of star-sights. The results of the combined ten-day and five-day data, when consistent, can hardly fail to command confidence, and even when inconsistent they give useful, though negative, information.

Although this work is not yet completed, it seems evident that the best chronometers show a remarkably regular change of rate for differences of pressure, running about $.10^{s}$ faster for a decrease of .10 inch of mean barometer. This amount is large enough to demand consideration in calculating mean data and resulting rate-curves, and it seems to be clearly established that the rate-curves of such chronometers should be drawn for a mean pressure of 30 00 inches, with similar curves to the right and left for each tenth lower and higher pressure, respectively, for, say, five tenths of an inch, for the practical use of navigators.

Unfortunately, there are no means available here for obtaining, artificially, mean high temperatures by which to observe rates, and thus fix more accurately the upper branch of the parabola, now determined from observations of one branch only, the vertices of the curves, as chronometers are usually compensated, lying about the maximum mean summer temperature. Thus slight errors, or variations of rate, may introduce decided errors in the curves as plotted from equations deduced from the observed data. Another necessity is a self-recording thermometer and barometer, for better temperature and pressure data, and a seismograph, in order to avoid errors due to earth-tremors not otherwise noticed.

It is not claimed that all chronometers show equally good results as regards effect of changes of pressure, but only the best of them. In fact, I find that when a chronometer shows decided evidences of polarity, the relation between rate and pressure seems sometimes to be actually reversed.

The plate entitled "Chronometer Rate-Curves" gives the lower branches of the temperature-rate parabolas calculated for the three standard Negus chronometers issued to the U. S. S. *Nero*, Captain CHARLES BELKNAP, U. S. N., commanding, now engaged in surveying for a cable route to Manila. Her navigator, Lieut. JOHN HOOD, has agreed to take special care with the thermometer and barometer record (not always very reliable, even aboard a man-of-war), and his report will be of great interest, as indicating the value of the method in actual practice. The absence of data at high temperatures, however, and errors that are liable therefrom, must still be remembered and allowed for. The first of the three curves is plotted from data observed with XII South, the other two from data for nearly equal intervals of time with XII North and XII South, care being taken to give equal weight, in obtaining mean data for the curves, to observations on the two headings. The data used to obtain mean values for a single point of the three from which the equation of a curve is deduced are inclosed by a dotted line. Such mean values are corrected to a normal pressure of 30.00 inches before being used in the equations, and the difference between the curves thus worked out and those that would result from the same data uncorrected for pressure is evident at a glance. For a long voyage, like that of the *Nero*, where accuracy of navigation is more than usually desirable, the value of this method can hardly be denied.

The data for the regular ten-day periods, as regards temperature, barometer, and humidity, are the same as for the mean-time clock. Additional data are as follows:—

Chronometer-Rates for 10-day Periods, October–December:

Period No.		1	2	3	4	5	6	7
Rates	1639 Negus,	...	—.75	—.83	—.97	—1.10	—1.69	—2.13
	1209	+1.08	+.96	+.95	+.73	+.64	+.33	+.20

Chronometer-Rates for 10-day Periods, January–April:

Period No.		8	9	10	11	12	13	14	15	16	17
Rates.	1141	...	—1.06	—.81	—1.32	—.92	—.58	—.75	—.95	—.60	—.41
	1639	—2.21	—1.90	—1.37	—1.56	—1.37	—.91	—.93	—1.14	—1.07	—.85
	1209	—.21	+.13	+.52	—.07	+.34	+.70	+.57	+.30	+.49	+.86

For Period No. 17½, 5 days ending noon, April 15th: temp. 65.20, bar. 30.02; rates, 1141 Negus, — .34; 1639 Negus, — .80; 1209 Negus, + 1.04.

Special 5-day Periods of High and Low Barometer (Data obtained from rate-curves of mean-time clock and daily comparisons of chronometers. Positions not plotted on the diagrams):

5 days end'g noon		Jan. 8	Jan. 14	Jan. 24	Feb. 3	Feb. 10	Feb. 25	Mar. 20	Apr. 6
Bar.		30.35	29.90	30.35	29.95	30.39	30 03	29.94	30.12
Temp.		48.10	48.80	54.85	56.50	48.40	62.55	54.25	62.45
Rates.	1141 Negus	...	...	—1.22	—.60	—1.78	—.43	— .93	—.50
	1639	— 2.37	—2.07	—1.70	—.98	—1.98	—.81	—1.19	—.88
	1209	— .27	—.01	+.18	+.58	—.46	+.83	+.35	+.64

All the data have now been given, and it remains only to explain briefly how the barometer correction has been obtained.

Taking the first chronometer (1141 Negus) as an example, we have:

Period No. 14:	Bar., 30.19	Temp., 59.25	Rate, —.75
10:	30.23	57.68	—.81
Mean:	30.21	58.47	—.78
Period No. 16:	29.98	58.43	—.60
Difference:	.23	.04	.18

The temperature difference being here so small, we can assume that the entire difference of rate is due to difference of pressure, which means that a difference of .10 inch barometer causes .08^{s} difference of rate. When the difference of temperature is appreciable, it is easily allowed for by estimating the direction of the tangent to the curve and applying a suitable correction.

Using now the data of the 5-day periods, we have:

Period ending noon, Feb. 25:	Bar., 30.03	Temp., 62.55	Rate, —.43
April 6:	30.12	62.45	—.50
Difference	.09	.10	.07

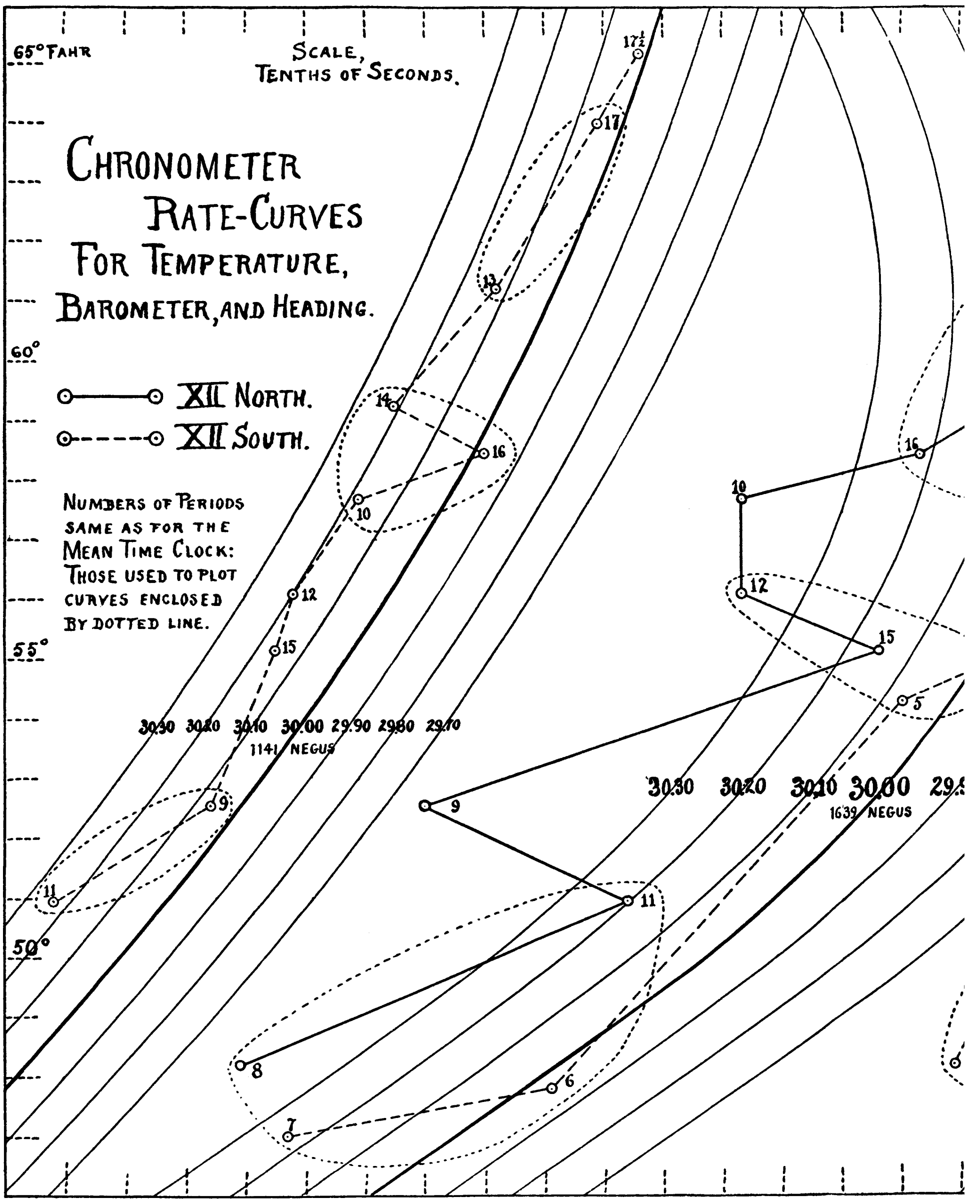
An approximate tangent to the curve gives, for temperature of 5°, a rate of .20^{s}, and for 0°.10 a correction of .004. Applying this correction, there remains a difference of rate of .066, caused by the difference of pressure of .09 inch. This gives, for .10 barometer, a difference of rate of .073^{s}, a close approximation to the former result of .08^{s}.

Again, using other 5-day periods,—

Period ending noon, March 20:	Bar. 29.94	Temp. 54.25	Rate — .93
Period ending noon, Feb. 3:	29.95	56.50	— .60
Mean:	29.94	55.38	— .77
Period ending noon, Jan. 24:	30.35	54.85	—1.22
Difference:	.41	.53	.45

Approximate tangent gives: 5° = .30^{s}; correction for 0°.53 = .032^{s}. Correcting for temperature, as before, we get: .10 bar. = .105^{s}. The mean of .073 and .105 is .089, showing that the rate of .08 first obtained was reliable. This correction is now used to reduce the means of points grouped together on the diagram, in order to obtain data for a normal pressure of 30.00 inches, and the three corrected means on each curve used to work out its equation.

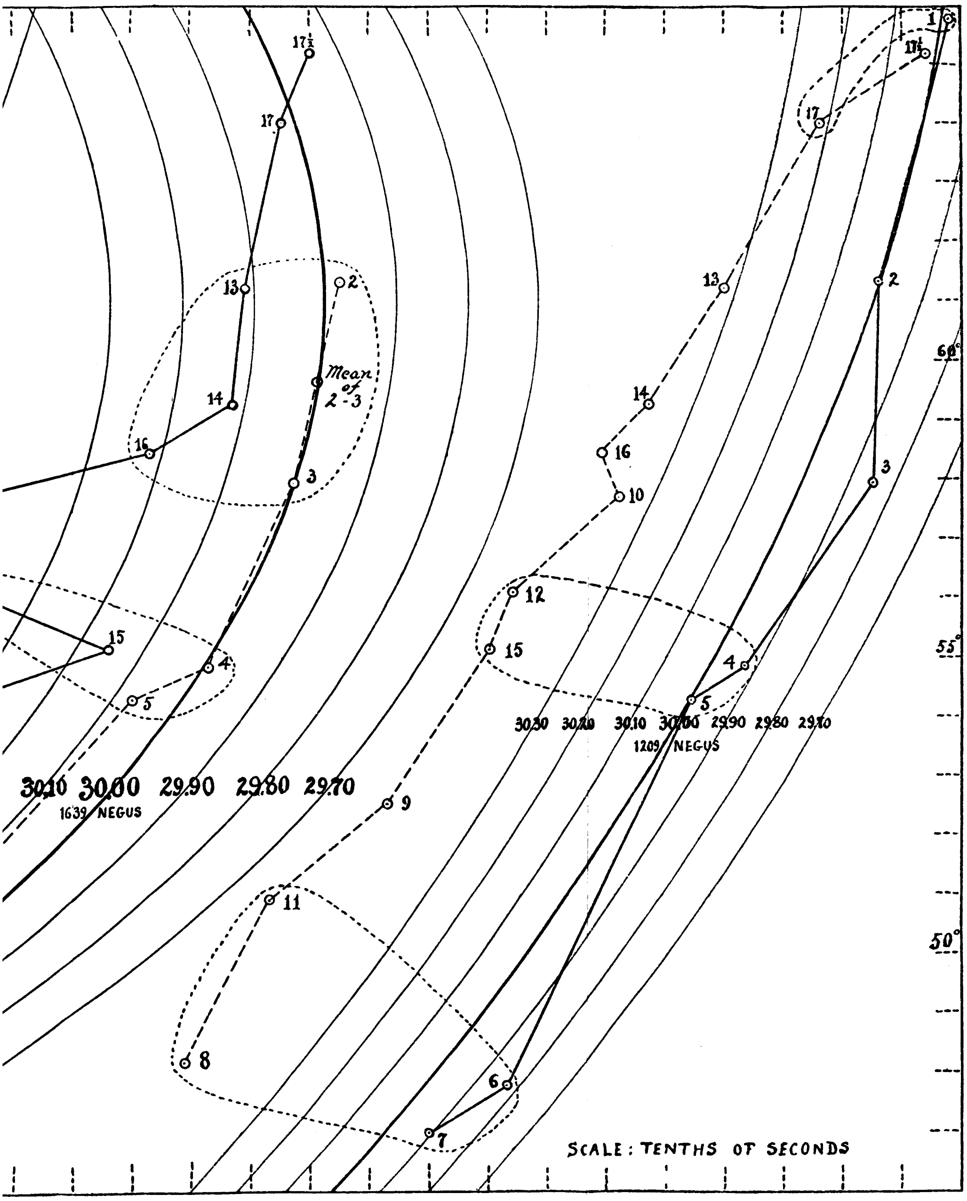
This same process was followed in the two other cases illustrated, although, there being data for XII North and XII South, an equal number of points on each heading were grouped together from which to obtain data for the equation of the curve.



CHRONOMETER RATE-CURVES FOR TEMPERATURE, BAROMETER, AND HEADING.

SCALE, TENTHS OF SECONDS.

NUMBERS OF PERIODS SAME AS FOR THE MEAN TIME CLOCK: THOSE USED TO PLOT CURVES ENCLOSED BY DOTTED LINE.


17½
17
13
2
Mean of 2-3
14
16
3
15
4
5
30.10 30.00 29.90 29.80 29.70
1639 NEGUS
9
11
8
6
7
1
17½
17
13
2
60°
14
16
10
3
12
15
55°
4
5
30.30 30.20 30.10 30.00 29.90 29.80 29.70
1209 NEGUS
50°
SCALE: TENTHS OF SECONDS

The results are in many cases so consistent as to convince any one that in those cases, at least, this method of correcting temperature rate-curves to a normal pressure of 30.00 inches, and of using the barometric rate in actual practice, is well worth a trial. Generally speaking, abnormally high temperatures accompany abnormally low pressures, and *vice-versa*, so that the use of data for temperature and rate, uncorrected for pressure, has an evident tendency to distort the resulting curve. The value and limitations of the temperature rate-curve are recognized, and this barometric correction should be recognized likewise.

THE MARE ISLAND OBSERVATORY, CALIFORNIA.

GEOGRAPHIC POSITION:

Lat., 38° 05′ 55″.8 N.
Long., 122° 16′ 19″.3 W.

Location, on the crest of a hill, about sixty feet above mean low water, and near the northern extremity of the island.

The observatory consists of two brick buildings, one of them two stories high, with a 5-inch ALVAN CLARK & SONS' equatorial (No. 861), mounted on a substantial masonry pier built up through the center of the building; the other brick building is the clock, chronometer, and chronograph-room, and the two are joined by a light wooden structure forming the transit-room. The transit-room contains three piers, two of them central, with sliding shutters overhead. Of these, only one set is now in use.* Leading out of the transit-room is a small hall-room, used as a battery-room. The transit instrument is of 2.5-inch aperture, No. 1508, STACKPOLE BROS., New York.

The three clocks are very similar to each other, and all are by E. HOWARD & CO., Boston. The mean-time and sidereal clocks are mounted on separate masonry piers, and have double cases. The transmitter-clock is hung to the south wall, and has but a single case. All three have mercury-compensated pendulums and gravity escapements. The first is No. 624, the second 627, and the third 622.

The observatory was established in 1884, through the efforts, principally, of Lieutenant (now Lieutenant-Commander) U. R. HARRIS, U. S. N., under the direction of Commodore JOHN H.

---

*One of the spare piers is now occupied by a Ewing seismograph, kindly loaned by the Director of the Lick Observatory.

RUSSELL, Commandant of the Navy Yard, and Commodore (now Rear Admiral) JOHN G. WALKER, Chief of Bureau of Navigation, for the purpose of supplying standard time to this coast, as the Naval Observatory, at Washington, does to the East and South coasts, and for the care and rating of chronometers (of which, as already stated, there are forty now on hand, running and compared daily). The principal object in view was then, and is now, the storage and supplying to naval vessels of accurately rated chronometers and the furnishing to shipmasters in any of our ports facilities for comparing and rating their own chronometers, either by means of time-balls, dropped electrically at noon, or by visits to the local telegraph offices, where the signals are received. Incidentally, the time service is, of course, of great general benefit and utility, but it should be remembered that the great modern improvement in accuracy of clocks, watches, and time generally is primarily due to and a result of the needs of navigators. The details regarding methods of rating chronometers are of great interest, but cannot be considered here. It may be of interest to mention, however, that chronometers cost from $200 to $500 apiece; that some still in use are as much as fifty years old; that several of these were captured during our Civil War, and that one of the best, if not the very best, firm of chronometer-makers in the world is located in New York.

Another service that has been performed at the observatory from time to time is compass and magnetic work, and the care and issue of sextants, portable transits, and meteorological instruments. The magnetic and compass work, however, is now carried on entirely by the compass office in Washington.

Other naval officers who have been in charge of or assistants at the observatory for a year or more at a time, to whom also credit is due, are Lieutenant-Commanders J. B. MILTON and W. E. SEWELL, and Lieutenants C. F. POND and D. P. MENEFEE. To Mr. POND, especially, who succeeded Mr. HARRIS, is due the completion of the transit-room in its present form. As a rule, there has been no assistant, and there is none now, all the work being performed by the officer in charge. Considering this fact, and the importance of the interests confided to its charge, its record is certainly creditable, but there is nevertheless urgent need for more of an element of permanency and continuity in its management, work, records, and library. An entire change every two or three years, while essential and desirable in ordinary naval routine work, is not very well adapted to work of this character.

Much credit for the practical efficiency of the time service is due to the Hydrographic Office and its branch offices for co-operation in connection with time-balls and other methods of distributing the time amongst navigators, and to the Western Union Telegraph Company, which also itself utilizes the time by correcting electrically many hundreds of clocks daily, and which has been of great assistance in connection with telegraphic longitude determinations and occasional time-signals to surveying vessels far south along the coast of Lower California.

If the investigation explained in the accompanying paper adds to the efficiency of this service, and to that of other services engaged in similar work, the writer will feel well repaid for the study and effort devoted to it at intervals between pressing official duties during the past six months.

THE RISE AND PROGRESS OF ASTRONOMY IN CENTRAL EUROPE.

By Sidney D. Townley.

During a stay abroad in 1895 and 1896, the writer obtained photographs of many of the observatories of Germany. It was thought that a reproduction of some of these views, together with descriptions of the buildings and instruments and short historical accounts of these observatories, would be of interest to the students of astronomy. In preparing the material for publication the scope of the work, as often happens, has been enlarged gradually, until it has reached that indicated in the above title. The title should perhaps have been somewhat restricted — for it is my intention to treat mainly of the practical or observational side of astronomy, and to touch upon considerations of a theoretical nature only in so far as is necessary to bring out the development of the practical branch of the science.

Six names, Copernicus, Tycho Brahe, Kepler, Galileo, Gauss, and Bessel, stand out pre-eminently prominent. These are almost household words to the student of astronomy. Their lives and works are familiar to nearly every one. Some of them